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Rapid Generation of Kilonova Light Curves Using Variational Autoencoder

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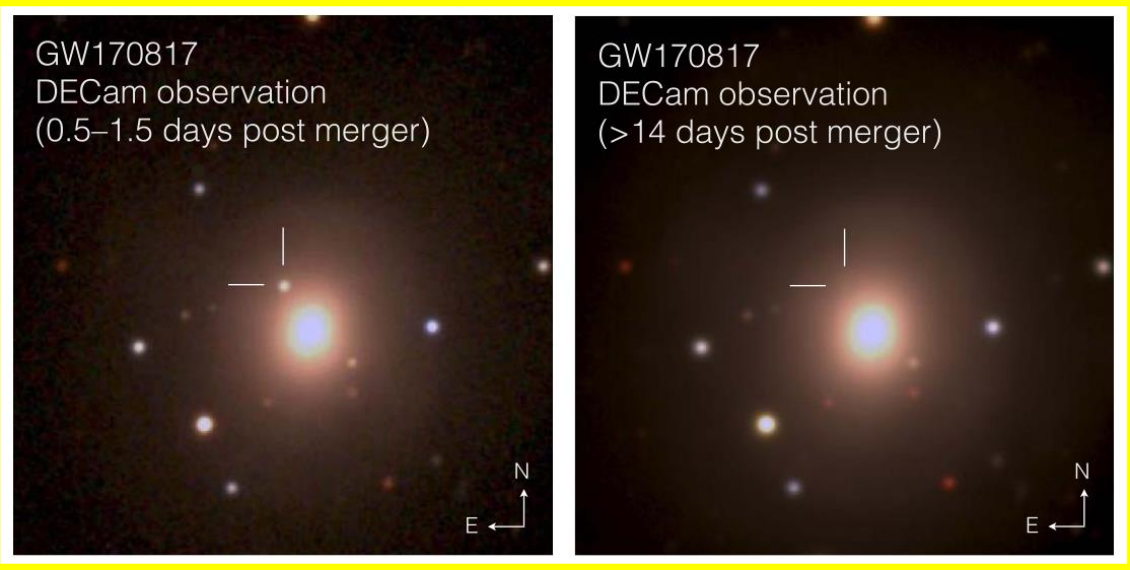
Matt Nicholl

Content

- Background and Motivation
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Beginning of a New-Era in Multi-messenger Astronomy

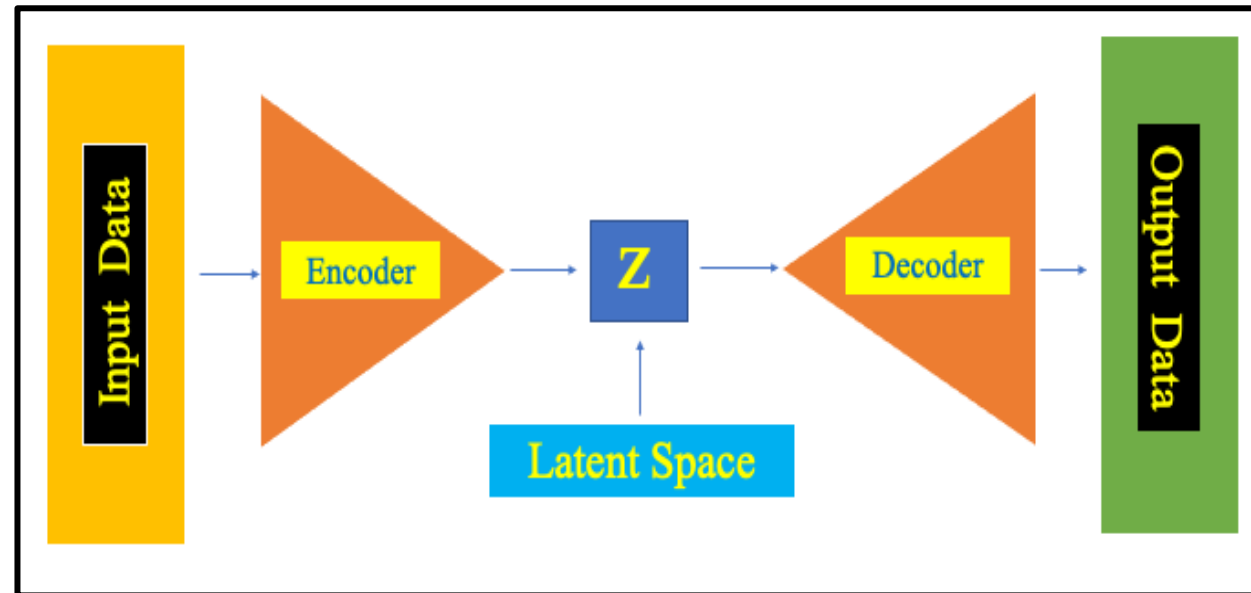
- ❖ On 2017, August 17 at 12:41:06 UT Advanced LIGO/Virgo detected a binary neutron star merger (GW170817).
- ❖ Alert was issued 40 minutes after the trigger.
- ❖ DECam followed up the observations. (Swope Telescope detected prior to DECam- [Coulter et al.](#)).



NGC4993 *grz* color composites (Soares-Santos et al.)

Follow up observations: Swope telescope, HST, GS/F2, Swift/UVOT

Autoencoder: Unsupervised learning technique where neural networks are used for representation learning.



Motivation

- ❖ Using conditional variational autoencoder (CVAE), as a method to generate light curves for the physical parameters of our choice.
- ❖ This method can also be used as a technique for model verification.

Methodology

- ❖ Build an autoencoder (AE) and test its performance.
- ❖ Prepare the data set to be fed into the AE.
- ❖ Check the initial results.
- ❖ Upgrade the AE to CVAE.
- ❖ Further check the results.

Total Data set: 329 light curves (Kasen model)
Time span: 0-25 days

Parameters

Ejecta mass: $10^{-3} - 10^{-1} M_{\odot}$

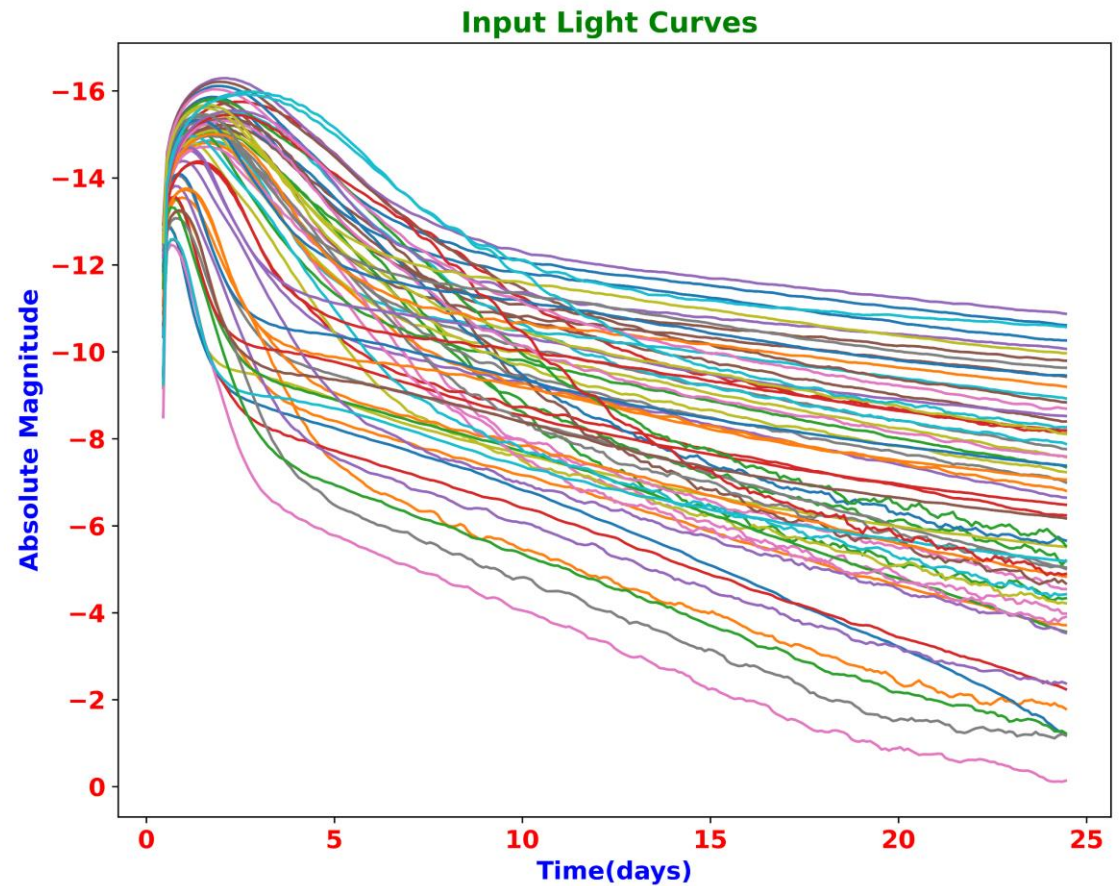
Ejecta velocity: 0.1-0.3c

Lanthanide fraction: 10^{-9} , 10^{-5} , 10^{-3}

Training data set: 147 light curves

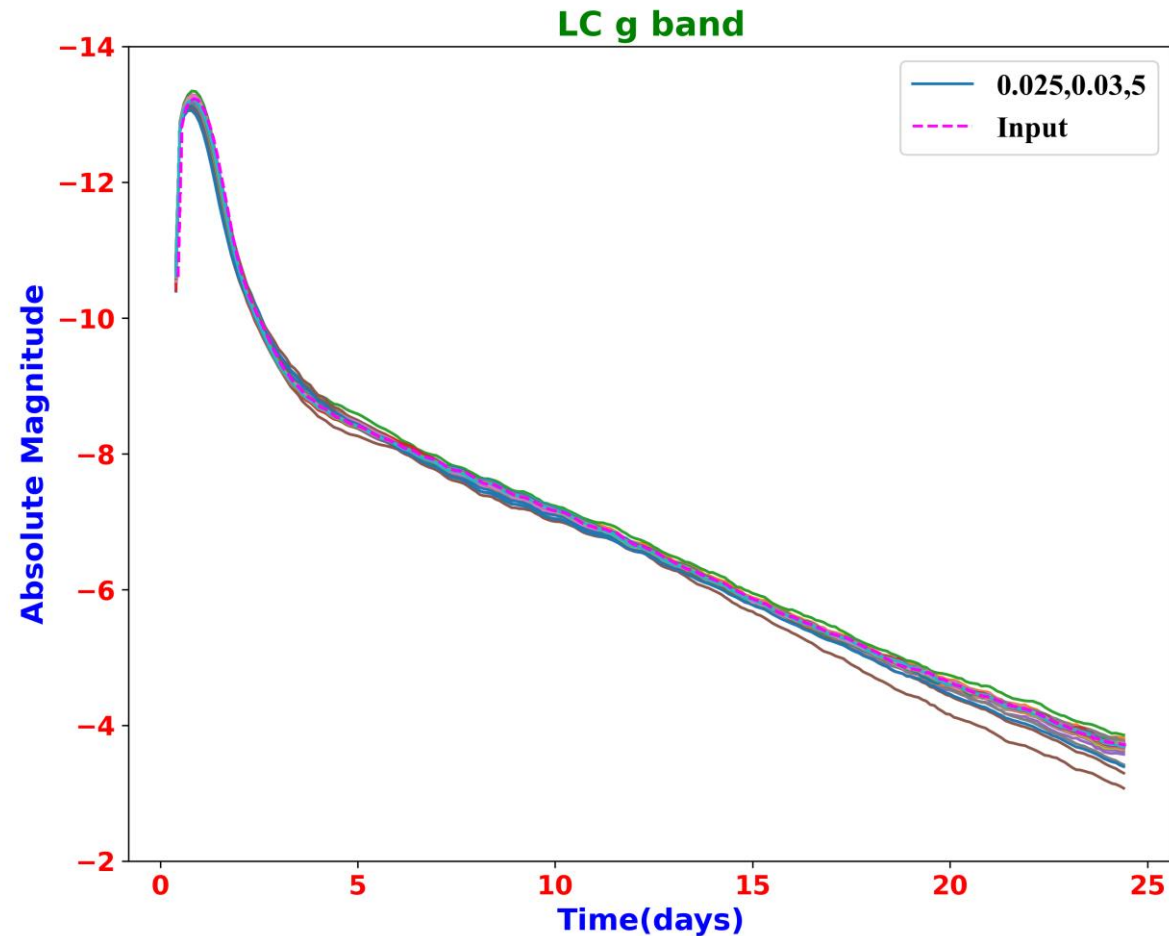
Test set: 61 light curves

Validation set: 61 light curves



Light Curves fed into the AE

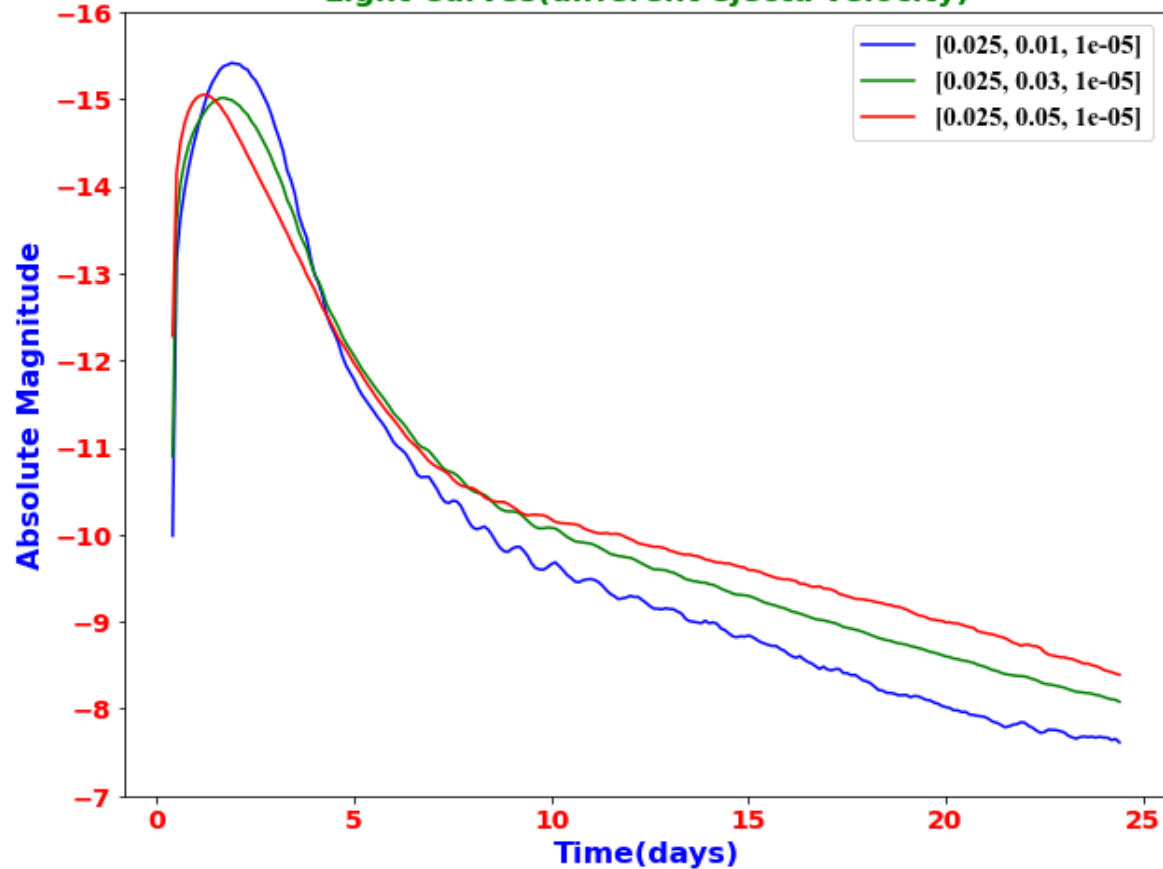
Results are shown for CVAE



- The light curve plot is for a particular set of physical parameter that was present in the training set.
- This ensures that the CVAE is working as per requirements.
- We can generate as many number of light curves as required for any range of possible physical parameter.
- Physical parameters must be present in the training dataset.

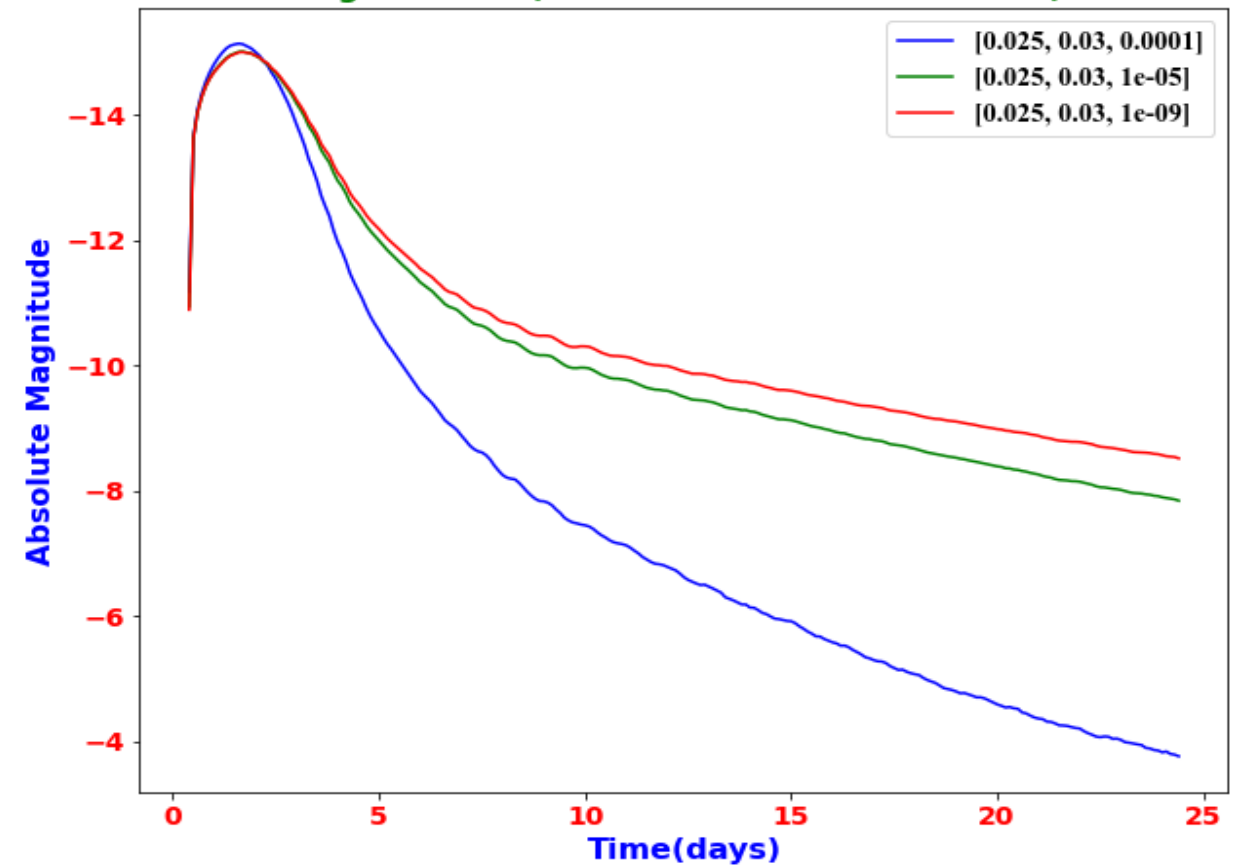
To verify our approach, we present light curves for the values of physical parameters that are not present in the dataset

Light Curves(different ejecta velocity)



Ejecta velocity: 0.01c, 0.03c, 0.05c

Light Curves(different lanthanide fraction)

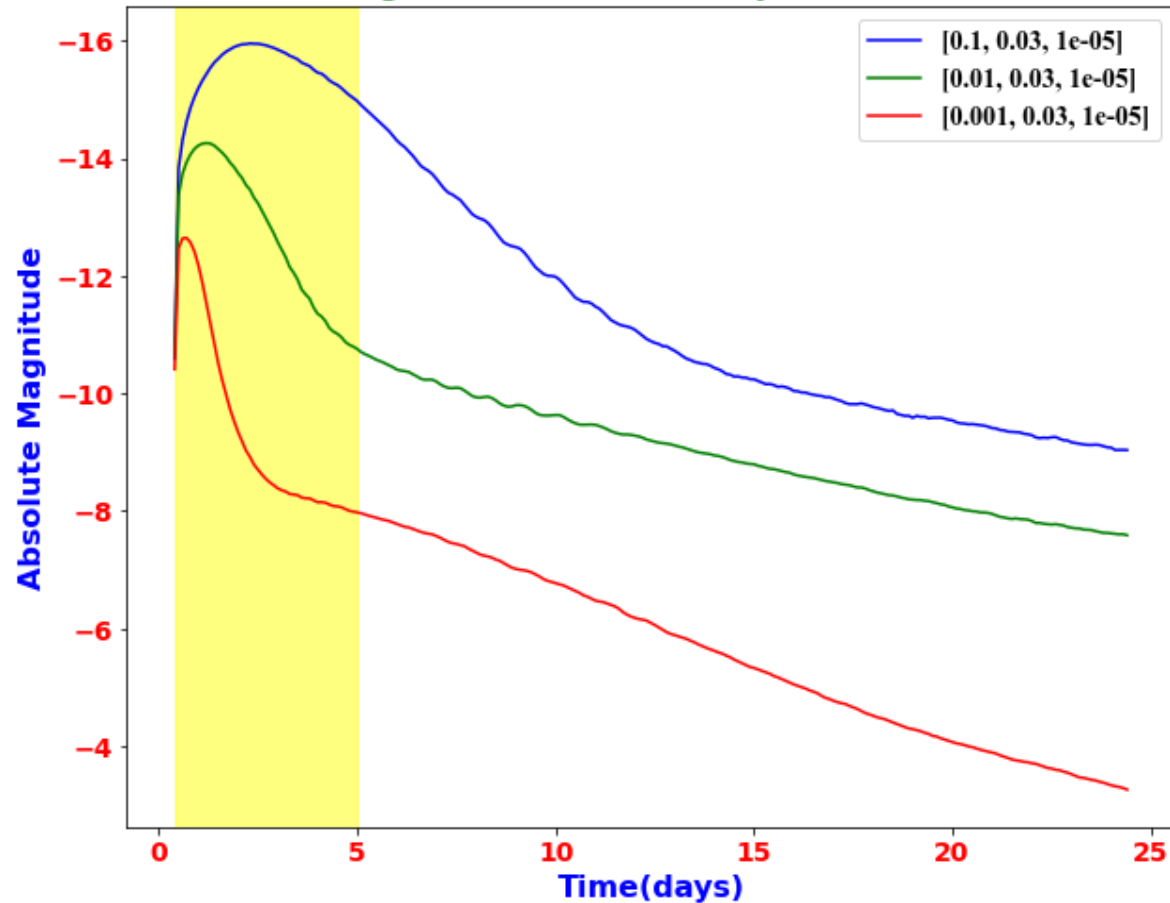


Lanthanide fraction: 10^{-3} , 10^{-5} , 10^{-9}

Current Results

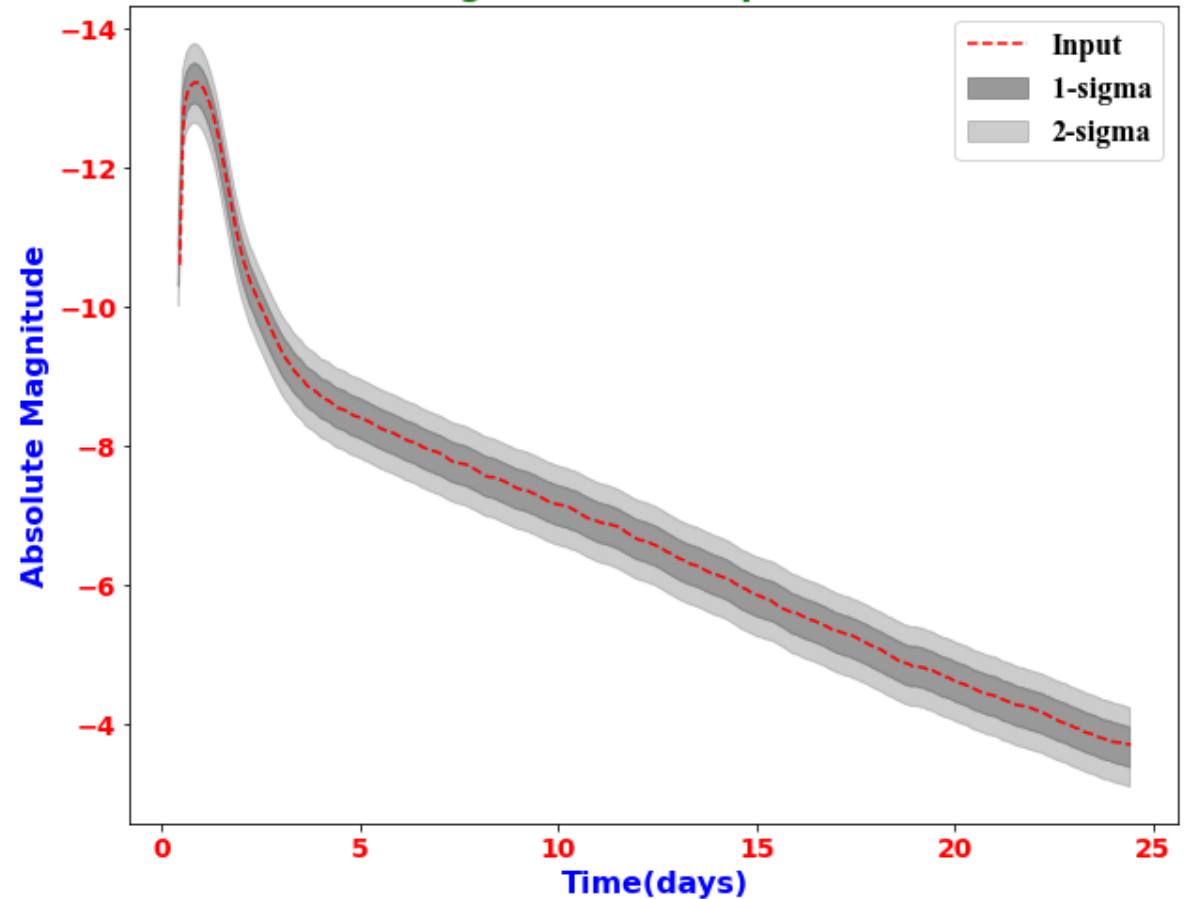
Ejecta mass: 0.1,0.01,0.001

Light Curves(different ejecta mass)



To show the confidence interval of the plot
Physical parameter: [0.025,0.3,1e-5]

Light Curve Comparison



Conclusions

- The light curves are extremely sensitive to ejecta mass compared to other physical parameters.
- The CVAE is working fine to generate the light curves.
- The execution time for training and generating light curves is about 1-2 hours

Currently Working

- The CVAE is being trained on data set from analytic kilonovae models for a wide range of physical parameters.
- This will provide a wide range of light curves corresponding to different physical parameters.

Thank you